THE PROCEEDINGS
of
THE INSTITUTION OF PRODUCTION ENGINEERS

The Official Journal of the Institution of Production Engineers

Members are requested to correspond with the Editor upon matters of general interest. Letters may take the form of descriptions of unusual plant or tools, workshop methods, production problems or organisation systems. Only in exceptional circumstances will proprietary articles be dealt with editorially. Manufacturers wishing to draw the attention of the Institution to the merits of their products are invited to use the advertisement columns of this Journal. All correspondence should be addressed to the General Secretary, Institution of Production Engineers, 48, Rupert Street, London, W.1.

VOL. VIII. SESSION 1928-29. No. 5.

THE DESIGNER VERSUS THE PRODUCTION ENGINEER.

Discussion on Address given by L. H. Pomeroy (Member), to London Section, 25th January, 1929.

MR. L. H. HOUNSFIELD (President of the Institution of Automobile Engineers) after congratulating Mr. Pomeroy on a most attractive lecture, said the only point he could think of by way of criticism was to submit that the wrong impression was given in stating that an expensive motor car might cost 5s. per pound and a cheap one 9d. per pound. This rather gave the impression that the greater the weight the better the value, whereas in actual practice it was often just the opposite. Efforts were constantly being made to reduce weight in the most expensive articles by using better and lighter materials which, however, had the effect of increasing the price. Therefore, it by no means followed that a heavier article was necessarily the best.

MR. HUTCHINSON said he did not see why Mr. Pomeroy should come to a meeting of the Institution of Production Engineers and liken the production engineer to the bricklayer. He had said that the designer is to the production engineer what the architect is to the bricklayer, and then suggested that the designer must have the architectural instinct. This appeared to be rather rubbing it in and suggesting that the production engineer should have the

bricklayer's instinct. It had also been suggested that the designer was the one person who had to consider the market and that the production engineer was merely somebody who did not count so far as that was concerned. Personally, he would rather say that the designer's sphere lay between the market and the production engineer with whom he included not only those responsible for machining but also the metallurgist, the foundryman, the steel maker and, in fact, all who contributed to the provision of the rough material and its conversion into a finished article ready for the market, and that the designer put down on paper what the production engineer, by his ingenuity, had made it possible for him to design. He felt that Mr. Pomeroy had thrown out a challenge to the production engineer but apart from any little rivalry between the production engineer and the designer there was one point upon which he did not agree with Mr. Pomeroy, namely, that everybody was in business merely to make money. It would be much more correct to say that we are all at work in common with every living thing in order to obtain the means of existence and it would be very discouraging to feel that we were all working only for the money to be got out of it. We must also remember that we were working for the advancement of civilisation. In saying that capital and overheads represented 25 per cent. and material 40 per cent. of the cost of production, Mr. Pomeroy did not take into account the labour expended in producing the material as supplied to the manufacturer. The 40 per cent. which he mentioned as representing the cost of material included a very large sum indeed for labour. Indeed, the bulk of it must eventually be labour. It was not quite clear either where the designer came in. Was his salary included in the 15 per cent. overheads? Again, Mr. Pomeroy suggested that the only person responsible for selling was the designer but the production engineer was quite as much responsible because it did not matter how difficult a design might be to produce it could never be put on the market at a reasonable price without the art of the production engineer. With regard to the interesting matter mentioned concerning sharp corners, the production engineer had been trained to treat tool marks and scores as anathema quite as much as the designer. There was one piece of information which would be very interesting because it was no good putting a radius on a fillet at the bottom of a key-way unless that radius was a smooth radius. Could Mr. Pomeroy give some idea of the effect of a sharp scratch at the radius at the bottom of a key-way? They had probably all passed through the phase when they had been told that something had broken because of a scratch on it and at the time probably most of them had thought it was all tommy-rot. It had not taken many of them long, however, to learn the tremendous importance of scratches and from that point of view alone Mr. Pomeroy's figures would be extremely useful. If, however,

he could add something as to the actual effect of a tool score in a stressed piece, it would be even more useful. With what had been said as to imitating America he thoroughly agreed, because he felt that if ever American ideas became thoroughly imbued in us over here, this country of ours would suffer very much.

THE PRESIDENT (SIR ALFRED HERBERT) who also paid a high compliment to Mr. Pomeroy for the entertaining manner in which he had delivered his lecture, said he did not think that making money was the most exciting thing about a business.

MR. POMEROY: It is if you do not make any money.

THE PRESIDENT continuing, said he had tried various ways of enjoying himself in this world and most of them consisted in spending money, but he had never found anything else which had such solid enjoyment in it as dealing with the problems involved in conducting a business. The feature which appealed to him about business was the element of sport and rivalry and once the spirit of competition disappeared from business, the whole incentive for progress went with it. There was in industry at all times a great need for stimulus if development must take place and it was the stimulating effect of Mr. Pomeroy's lecture that appealed to him so much. It was possible to define a good book or a good lecture as one which, after reading or hearing it, left us a little disturbed in our minds and certainly Mr. Pomeroy's lecture must leave them all a little disturbed in their minds, because he had shaken up some of the mouldy old views which existed in many directions, and personally he was convinced it would do a great deal of good. He had been particularly impressed with the insistence upon the necessity for change. Life itself was always changing but there was a tendency for production engineers at times rather to resent changes and to curse if any were proposed, but production engineers must come forward and help the manufacturers to make changes with the least possible expense in order to improve the product. As regards the suggested rivalry between the designer and the production engineer, personally he did not look upon it as rivalry at all, but as collaboration and co-operation and that each one would considerably benefit by having some experience of the other's province. He knew from experience that the production engineer often made a very sound designer, whilst on the other hand, a designer who moved to the production department often turned out to be a splendid man in that work. He was a great believer in appreciating each other's problems and troubles, but when all was said and done, he held the view that the designer must be number one and the production engineer number two. It always seemed to him that "what" was more important than "how" and that it was a greater thing to know what to do than how to do it.

MR. PATTINSON suggested that the title of the lecture should not be the "Designer versus the Production Engineer" but the

"Designer relative to Production." His experience had been that if anything was required in six months, the designer usually took five months and three weeks to get out the drawing and the remaining week was usually occupied in getting the drawings returned back to the shops and corrected. Some years ago in one large factory it was found necessary to appoint a man known as the trouble engineer. His duty was to keep in contact with the drawing office and the manufacturing departments and, as a matter of fact, he did not have to look for trouble, he found it every time he went to the drawing office. It was the fact, however, that this man was able to do quite a lot of good work in walking around the shops, for instance, and seeing the fitters doing unnecessary work on a part. Investigation often showed that by a slight alteration the amount of work done in this way could be considerably reduced if not eliminated, and the difficulty arose simply by lack of co-operation between the manufacturing departments and the drawing office. As regards the United States, he happened to be out there a few months ago and went into one large factory well known in New York which had a department called the Development Department, which was an intermediate department between the drawing office and the shops. He made some inquiries about it and was told that the department set out purposely to deal with errors of the draughtsmen and to get about the shops and see where things that did not function on paper but were found to function in practice were recorded on the drawing, and in this way he was assured that considerable savings had been made. Obviously, the answer of all production engineers would be that the drawing office was inefficient but anyhow that was the position in this very large factory, the management of which thought was justified. Another thing which might be interesting was that he had met in New York a gentleman who had been specially detailed from Dayton College to investigate the reasons of the slowing down of the production of American workmen. This man had investigated different factories and stated definitely that there was a decided falling off in the production of the American workmen to-day. This gentleman would shortly visit England and he hoped the Institution of Production Engineers would be able to get him to speak at one of their meetings in view of the unfavourable comparisons that had often been made between the output of American workmen and British workmen. Without wishing in any way to advertise, he mentioned that the firm with which he was engaged was turning out some of the largest printing presses in the world, 130 feet long and 25 feet high, weighing about 170 tons. In such a piece of mechanism it was essential that every detail should synchronise perfectly and the practice followed was for the production department to keep in the closest possible touch with the drawing office because by doing that it had been found possible frequently to cheapen production

and increase output. On mass production there was a wonderful field for team work between the production engineer and the drawing office. Apart from the two keeping in constant touch they could go farther and keep a record of every jig and fixture in the place so that when the designer was getting out his design it would be possible for him to find that an existing fixture which probably cost £100 could, with a slight alteration be used and thus obviate the necessity for making extra tools.

MR. GARTSIDE said that whilst agreeing with Mr. Pomeroy that standardisation could be over-done, it must also be admitted that etandardisation was a very important thing. One of the finest xamples of standardisation in this country was Meccano. That was his idea of standardisation, namely, that numerous parts should be standardised in such a way that they were capable of constantly being made up into different designs. If this principle were applied to the heavier forms of engineering it would be a simple matter for various parts to be standardised in a way that would in no way stagnate design. For instance, he saw no reason why every machine tool maker in the country should not use the same hand wheel for their machines or the same change wheels. At present, machine tool makers had their own designs of change wheels with the result that one saw a pile by the side of every machine tool. If these, however, could be standardised there would be a great saving. The same thing applied to bushes, bearings and similar items. Mr. Pomeroy had referred to the standardisation of the Stauffer lubricators, but at the same time there were people who used them to-day and the fact that hey had been standardised had really been of benefit.

MR. HANNAY said that one thing which production engineers had to learn more than another was to mind their own business. Nobody had more respect than he for the designer and he believed that we led in the engineering industry to-day through the ideas and ability of our designers. At the same time, he did not think Mr. Pomeroy quite understood what the position of the real production engineer is. His own views on the matter were that the designer was the first man the production engineer must follow and make what the designer planned. Everything should be done to support designers by following out absolutely every detail they called for and to throw the whole responsibility on to them. It was no use production engineers pretending to be designers. If he were a designer and a production engineer told him how a thing should be made, he would soon get short shrift, and in the same way it was out of the question for the production engineer to tell the designer what he should do. He did not like interference with designers and it was for that reason that he urged production engineers to mind their own business and do what the designers desired. The job of the production engineer was to produce and not to bother themselves

with design or salesmanship, because as long as the establishment was large enough to carry everybody the position of the production engineer was between the designer and sales. As to the 10 per cent. mentioned by Mr. Pomeroy for labour, it did not seem in the case of motor car manufacture that there was very much to save. He was pleased, however, that Mr. Hutchinson had raised the question of material. This had been brought to his notice several times and he also held the view that this 40 per cent. for material was in regard to labour. After all, material was free to everybody and the real cost of it was the labour entailed in getting it from its original source and bringing it to the place where it had to be worked up, and there was an enormous saving to be made in tackling that question of labour upon raw material.

MR. POMEROY replying to the discussion, agreed with Mr. Hounsfield that in the case of aero engines for example, the whole desire was to keep down weight, but the point he had made, he contended, still held good, although in the case of the aero engine the purchaser paid for the least weight. With regard to Mr. Hutchinson's remarks, the difference between himself and Mr. Hutchinson was rather in the matter of definition. He recalled that at the very opening of his lecture he had disclaimed the title which had been given to it in the notice announcing the meeting, namely, "The Designer versus the Production Engineer." That was not the point at all—it was the relation between the two and he hoped that nobody had missed the correction he had made. He could not agree with a great deal that had been said about team work, because team work meant that everybody shared the blame and nobody was responsible. In one works he was in, on one occasion there was a man who was called the Treasurer and one day a man came in and said, "Who is the boss here?" The Treasurer promptly replied, "You start something and find out!" Therefore, in his view, there must always be a boss or somebody who will go round and raise hell and fireworks and everything else if things were not as they should be. All this co-operation and fraternal love sounded fine, but actually there must be a definite discipline in business. When he said that we were in business for the sake of making money, it must be remembered that in ninety-nine cases out of a hundred they were making money for the shareholders and every shareholder who put his patrimony into making a motor car or anything else, looked for profits. When it was stated that what we worked for was greater happiness and improvement, this really resolved itself into earning money, because the two were absolutely intermixed. He quite realised as one with some pretentions to having studied political economy that all material was the summation of labour, but on the other hand, it must be remembered that the man who cut down the trees, for instance, to provide timber did not do it with his finger nails. He bought a hatchet or a saw and had to do something

or other, and right the way through the story he believed it would be found that the relation between labour and material was about 1 : 4. Although he had stated that in the case of the motor car material represented 40 per cent. of the total cost, that figure would, of course, get smaller as we went farther back towards the original source of the material, but taken as a general rule it would be found that materials and labour were in the ratio of 4 : 1. Mr. Hutchinson had asked a very difficult question, namely, what was the effect of a sharp scratch at the bottom of a key-way? He could only answer it by asking "How sharp?" Certainly, he would rather have a sharp scratch on a radius than a sharp scratch on a key-way. Sir Alfred Herbert had also questioned his remark that we were in business for making money, but when he was in America he spent one million dollars of somebody else's money and was always being told that they were in business for making money. It might be a little crude but it seemed to him a solid fact.

In reply to Mr. Pattinson, Mr. Pomeroy said he regarded the draughtsman more as a particular sort of mechanic, whilst the designer he looked upon as the man who sketched out an original concept which was passed down the line for anybody to express an opinion upon, but there must be some sort of water-tight department for the designer. At the same time, he held the view that there is no training in the world so valuable as that of a draughtsman for making a man think exactly and making him methodical and accurate. His view of the functions of the designer was that if he were told that a four-speed gear box or something else was wanted which would hit off the very peculiar thing called fashion, which had to be provided for six months ahead, he would sketch it out and then let everybody express an opinion upon it even down to the workmen, but it would be the designer who must in the end be responsible. The remarks by Mr. Gartside were very valuable and he agreed at once that we must have some standardisation. What he was anxious to prevent, however, was the state of mind that we wanted a standardised man. He personally did not profess to be standardised and anybody who attempted to standardise him would have some job. Had it ever been realised what an enormous advantage nuts with seven sides instead of six would be (sketch), because it was possible to have a spanner like that (sketch) and use it on half a dozen different size nuts, but there was a big difference between the standardisation of small details and standardisation in design, as Mr. Gartside truly said. At the same time, standardisation must be related to the question of artistic consideration. Art and the production engineer had a lot to do with each other and as soon as we had taught every child coming from school to realise the difference between something which was ugly and something which was beautiful, then we should have made the greatest step towards the elimination of unemploy-

ment and every social evil that could possibly exist. It was obvious that if everything was standardised and the scope for the ability of the individual was eliminated, we at once ran against the danger of over-production. In spite of the views of some people, there was the danger at certain times in the development of the world of over-production and he felt it was better to be making things which called for a considerable degree of handicraft or skill than to be making a standardised article which had no artistic concept in it at all. A great many things required in the world were difficult to make, but he believed it would be only by working on these lines that real progress in the world would be made, rather than by trying to standardise everything and satisfy the whole community in a very short time.

MR. HUTCHINSON who had taken the chair, owing to Sir Alfred Herbert having to leave to catch a train, moving a hearty vote of thanks to Mr. Pomeroy also expressed pleasure at the presence of Mr. Hounsfield, the President of the Institution of Automobile Engineers.

The vote of thanks was carried with acclamation.

PRODUCTION IN THE FOUNDRY.

Paper presented to the Institution, Birmingham Section, 30th January, 1929, by D. Wilkinson.

THE dictionary tells us the word "foundry" is derived from the Latin "fundere" to pour, and as a foundry is concerned with metals, we may briefly describe its functions as the melting and pouring of metal. This definition covers a very wide field. Logically, the production and pouring of molten metal, whatever shape the metal may assume on cooling, is a foundry operation and the plant thus operating is a foundry. The winning of metals from their ores was originally a branch of founding, and the man who produced the metal, also produced the castings that were required from it. To-day many works operate blast furnaces and make, from the pig iron, large quantities of castings. In some works the molten iron is taken direct from the blast furnace and made into castings instead of being first cast into pig iron. But it has become customary to differentiate between the smelting of a metal from the ore and the utilisation of the metal after it has been thus obtained. Even where a works operates a blast furnace and uses the iron directly for the manufacture of castings, custom still differentiates between the two processes, limiting the term "foundry" to the shop in which the castings are made.

As our time to-night is limited, we propose to observe this distinction and omit all consideration of recent developments in blast furnace practice, steel making, copper smelting, electric furnace construction and the modern processes used to produce the various metals which have come into engineering practice during the present century.

Recent advances on what may be called the metallurgical side of foundry production are so extensive that they may almost be said to be epoch-making, but as it is not possible to deal with the entire subject in one evening's discussion, we will pass them by.

We will commence with the metals as used by the engineer. From this starting point progress has taken place along two lines.

1.—The development of new metals and alloys.

2.—The cheapening of methods of manufacture.

1.—We shall not dwell at any considerable length upon the recent developments in alloys and new metals, as these are fairly well known and to do full justice to any one of them would seriously encroach upon the time required to consider the progress made in methods of manufacture, so we shall content ourselves with a brief enumeration of them and pass on to the second line of development.

The metals commonly used in the foundry at the end of the last century numbered only about half of those in regular use to-day. They were iron, nickel, manganese, copper, zinc, tin, lead and, for certain purposes, antimony and bismuth, with aluminium just coming into use. To-day we have in commercial use in addition to the above, chromium, cobalt, vanadium, titanium, magnesium, molybdenum, tungsten and quite recently cadmium, which is now being produced at a commercial rate and is being used for special alloys.

Aluminium, which at the end of last century was only just coming into use, now occupies a very prominent place among foundry products, both in the quantities produced and in the number of alloys in which it is used. The annual consumption of this metal is rapidly approaching 250,000 tons and it occupies the fourth place in the order of importance in the world production of the non-ferrous metals.

Many engineering achievements have been made possible by such alloys as duralumin and the aluminium silicon alloys, to say nothing of the vast number of uses to which the earlier known alloys of aluminium are now put. Modern engineering has been very definitely enriched by the steadily increasing use of the metals chromium, nickel, cobalt, vanadium, titanium, molybdenum and tungsten. These metals are used in many alloys whose absence would greatly impoverish the modern designer and craftsman. To mention only a few instances, many valuable steels and some alloy cast irons owe their existence to these metals, while the bi-chrome heat-resisting alloys have made possible the electrical heat-treating furnaces, whose constant temperatures and neutral atmospheres are of such great assistance to the engineer.

Magnesium alloy castings are now being used in increasing quantities. With mechanical properties about equal to those of the best aluminium alloys and a specific gravity approximately one-third less, it will be seen that where weight saving is important, castings of this metal may be of great value. The properties of this metal and its great reactivity in the molten condition gave rise to an involved series of difficulties to be overcome before castings could be successfully produced.

Cadmium is now beginning to make itself known as a metal of definite value. It possesses valuable alloying properties. While it is still early to claim for it an importance equal to some of the other alloying metals, it may very safely be asserted that the near future will know more about this metal than the present does.

Much the same tone may be adopted in speaking of the metal beryllium, which is now seriously engaging the attention of the metallurgists. Its present high price prevents its general adoption, but used as an alloying element with aluminium, a useful future is anticipated for it.

At the end of last century and during the first years of the present one, small steel castings of light section could only be obtained with the utmost difficulty. To-day they can be obtained in any required quantity or design.

Malleable cast iron has also undergone very considerable improvement in quality. It is now possible to obtain these castings with a minimum elongation of twelve to fifteen per cent. instead of the four or five per cent. which was the best that could be obtained not so many years ago. As regards cast iron, the metallurgical knowledge which has been acquired of this material has resulted in a very definite increase of strength being attainable. The cast iron used for high grade engineering castings by any firm of repute to-day is at least ten to fifteen per cent. better in tensile strength than it was a few years ago. With synthetic cast iron, which is produced in the electric furnace, a tensile strength of over twenty tons per square inch can readily be obtained. Almost equal strengths can be obtained by the use of alloy or specially treated cast irons. Very valuable properties are conferred upon cast iron by nickel, chromium, vanadium and titanium, and castings in which one or other of these alloying metals is used are in regular production.

2.—Taking up the second line along which progress in foundry production has been made, moulding machines naturally suggest themselves as a first consideration. Hand-rammed pattern-drawing moulding machines date back some eighty years or so, but recent years have seen the development of several types of power moulding machines, which in certain lines of work have been productive of great economies in labour. The application of power to moulding machines inevitably drew attention to the amount of time lost while the moulding boxes were brought into position, the sand was being put into the box and the mould was being taken away from the machine. The result of this was the application of power to the preparation and conveying of the sand, the removal of the completed mould and to the return of the empty boxes to the machine.

As sand is an intractable material to move mechanically, much trouble was experienced in the first attempts to deal with it. The main difficulties have now been overcome and the mechanical handling of all the materials necessary for the production of castings is an accomplished fact. It is not always clearly understood how much material has to be handled in order to produce a casting. Even experienced foundrymen have sometimes been incredulous when the weight handled per ton of castings has been mentioned. Naturally, the amount varies with different classes of work, but the production of one ton of light castings in either iron or steel, even with the aid of first class machines both for moulding and sand mixing, may require the handling of as much as 160-170 tons

of material. The different materials necessary and the number of times these materials require separate handling, easily total up to this figure, and in some instances even exceed it. With so great an amount of material to be dealt with, it can readily be seen there is ample scope for the application of power, providing the initial difficulties can be overcome.

Machinery for the preparation of sand has long been in use, although until recent years it was rather crude. One of the first improvements was the transporting of the sand from the casting floor to the preparing machines and its return to the moulding machines by elevators and conveyors. Coincident with this development was another for the removal of the moulds from the machines and these two improvements reduced materially the heavy labour previously done by hand. Following on, the next step was to convey the completed mould to a place where it met the metal and was cast and the mould and casting were conveyed from the casting point to a place where the casting was removed, the sand and boxes separated and each returned to its respective place.

To-day, where the demand for castings justifies the capital expenditure, the mechanicalisation of the foundry is complete, with the result of an enormously increased production and a considerable reduction of costs. Where the demand varies so much that a heavy capital expenditure is not justified, a partial mechanical handling has proved exceedingly effective.

Very definite limitations to certain lines of advance are imposed by the high melting points of most of the more serviceable metals. It would be an unquestionable advantage to economical production if castings of iron, steel and the bronzes could be made to accurate limits with a perfectly smooth surface so as to avoid machining. It is quite safe to say that this end is, as yet, very far removed, and at the present no clear way towards it exists for the following reasons.

1.—The difficulty of confining highly heated, mobile and weighty masses of metal within very fine limits.

2.—The disintegrating effect of the heat and movement of the molten metal upon mold surfaces.

3.—The natural irregularity of cooling—as the outside cooling before the inside—which leads to an irregular contraction in volume, so interfering with accurate adjustment of sizes.

4.—Chemical reactions that occur in the metal or between the molten metal and the material composing the mould.

Regarding these limitations, an audience of engineers does not need reminding that it is not an over easy matter to work to very fine limits. In machining, at least two operations are required to secure a moderate accuracy of finish.

In the foundry it is not possible to carry out even one finishing operation upon the casting while it is being made. Whatever

accuracy is obtained in the mould will remain mould-accuracy, not necessarily casting accuracy. Even when the metal has been poured into the mould a casting does not yet exist. We have only a volume of molten mobile metal confined in a space which may be disintegrating slightly and is most certainly changing its shape and condition definitely under the weight of the metal and the action of the intense heat. Before a casting can be said to be made, various thermal, volumetric and chemical changes must take place in the metal and during the whole of this time it is impossible to do anything to control dimensions. It is not too much to say that an ordinary casting is never seen until some little time has elapsed after all the work possible has been done to make it. All the work has to be done prior to the existence of the casting, and to control the sizes of an unseen, non-existent article is not at all an easy matter. We have only to think of applying exact measuring instruments or delicate finishing operations to the metal while it is cooling from the molten state, even if access to it could be obtained, to realise the very definite limitations that are imposed.

The volumetric changes that occur during cooling and contractions are by no means small. The specific gravity of molten cast iron is 6.7. The specific gravity in the solid state varies with the quality of the iron. For a strong close-grained cast iron it will be about 7.3 or 7.4. This difference means a theoretical reduction in volume of from eight to ten per cent. It will be noticed that this theoretical reduction in volume does not correspond with the ordinary contraction allowance in grey iron castings of one-eighth inch per foot. It is this difference which is one of the difficulties in the way of transferring accurate mould measurements to the resulting casting.

Obviously it is impossible to expect every part of a casting in an ordinary sand mould to solidify at the same moment. The first metal poured into the mould will, in moving over the cold sand, lose more heat that the last metal that enters over the already heated sand. It is thus difficult to see how a complete uniformity of temperature in every part of the mould can be secured. Then there are very few castings which are not irregular in section and consequently, uniform cooling and solidification is not possible. In any case, the outside must necessarily solidify and become rigid before the inside.

This is looking at contraction entirely from its physical side. But there is also a metallurgical aspect. The metals used in the foundry never solidify at a definite point of temperature. They solidify over a range of temperature, not at one point. This means that for some length of time there will exist in the metal both solid and liquid particles side by side and these solid and liquid particles will differ in composition and consequently in contraction, sometimes by an appreciable amount. The net result is that solidifi-

cation and contraction are decidedly irregular, and voids form in the casting which may or may not, according to their location, be filled by the infiltration of addition metal from the gates and feeding heads. This additional metal, which is in excess of the amount originally filling the mould, accounts for the difference in the volume as calculated from the contraction allowance and as calculated from the difference between the specific gravity of the molten and solid metal. The sum total is that there are so many variables affecting contraction, all of them difficult, and some of them impossible to control, that the transference of accurate mould measurements to the resulting casting is a matter of the greatest difficulty, not to say impossibility.

These natural limitations are very definite obstacles to any attempt to secure extreme accuracy in a casting. They also operate very effectively as obstacles to any attempt to secure entire solidity in a casting, and to minimise their effects calls for a high degree of craftsmanship.

A consideration of these limitations suggests a method for overcoming some of them. If the mould can be made of a rigid material, the first difficulty will be removed. According to the resistance of the rigid material to the action and movement of the molten metal, the second difficulty will be minimised. But the third and fourth limitations will not be removed, but it may be possible to reduce the time during which they may influence the cooling metal and so reduce the extent of their action. The so-called permanent mould, made of metal, very definitely eliminates some of the irregularities which result from the mobility of the metal.

For metals of a very high melting point, it is quite evident that much care will be needed to design a mould that will not be destroyed by the extreme heat to which it will be subjected. For instance, a grey iron casting of massive form weighing several hundredweights will have sufficient surplus heat to destroy any ordinary metal mould, however heavy it may be. For many years' attention has been given to problems of this nature, but during the last few years, in at least one instance, a complete solution has been arrived at. By applying centrifugal force to molten iron in a metal mould, sometimes water-cooled or sometimes air-cooled, it is now possible to produce a variety of castings.

Discussion.

MR. J. A. HANNAY, who presided, said that after listening to Mr. Wilkinson's paper, he had not much doubt about his having convinced them. They heard from America of castings being made right from the blast furnaces. To his mind that seemed very

dangerous. He should like to hear Mr. Wilkinson tell them something about it. From what Mr. Wilkinson had told them, foundrymen were to be congratulated on having moved in recent years. He was distinctly of the opinion that steel castings had improved very much. One point he would like to bring specially to their notice was that foundries claim the right to a certain amount of scrap. They supply you with castings and are quite content to take a number back. He wanted to try and get some idea as to what should be a fair percentage of scrap. He realised the troubles and difficulties that foundries had to deal with, the difficulty of contraction, and so on. What he would point out was that users of castings were content to submit their requirements to the foundry and wait, again and again, until samples were supplied and after the foundry had really produced something that was satisfactory, and were asked to proceed, they could not maintain those samples. He did not mind how long he had to wait to get a sample, while they made the necessary experiments, but once they were right he expected them to be able to go ahead. He was interested, a few months back, when he had the privilege of going to the U.S.A., and watched the sheet metal work, to find that the users of sheet metal had set a certain percentage, which was reasonable, say for 100 tons of sheet metal. If the scrap was not more than three per cent. they did not worry at all. As soon as it was over three per cent. the men had to come down from the mills and give an account. He thought that anyone who was not employed in a foundry would be amazed that, to produce one ton of castings, 160 to 170 tons had to be carried about. That was where the money goes for our castings. He would like to know from Mr. Wilkinson what amount had to be carried about in centrifugal process ?

Mr. P. Pritchard congratulated Mr. Wilkinson on two things. First of all his nerve in tackling such a tremendous proposition. Mr. Hannay in his opening remarks threw down a challenge to foundries when he stated that they had not kept pace with engineering practice. He would not attempt to defend that charge, but he did think that engineers who were criticising the foundry were the people most to blame for that. Only that afternoon he had an instance which would illustrate the point. A foundry firm was proudly shown a new machine for machining pistons which cut down the time by about one minute. On asking the price of the machine, he was informed that it cost about £1,100. He would like to know what foundryman dare ask his managers for anything costing £1,100 to save one minute in casting. He dare not ! The other point was, the foundry to-day was not being given the same attention as regards capital outlay for plant wherewith to make its castings as the rest of the engineering departments. They were not being supplied with the right kind of man. There again he

thought the engineering trade, in a sense, was largely to blame. Money was spent, one might say, lavishly on training skilled engineers, designers, etc. The foundry was, through lack of funds, unable to train the right type of man in the first place. Secondly, the reward for such men was not sufficiently high to induce the proper class of man to take up the study of foundry engineering. Thirdly, he would wish that Mr. Wilkinson had talked a little more upon the question of material. That was a point which is not receiving the attention which it deserved. They were being called upon for something new, more particularly cast iron, for easier and quicker machining, and on the other hand they were being tackled from the service department for cast iron of a better wearing quality. It was impossible to give both, and he thought some standard should be made or a decision given as to which of the two departments they were to satisfy. The Chairman had mentioned the question of casting direct from the furnace. His only reply was that the British Engineering Standards Association specified that high-grade casting must not be made direct from the blast furnace.

Mr. E. Player thought that Mr. Pritchard had put up a very fair case for the defendants. Being in the dock along with him and Mr. Wilkinson and several other gentlemen, the least he could do was to try to get out of it by offering as good an excuse as possible. There lies a good deal in what Mr. Pritchard had said regarding the attention given by people responsible for training suitable men for the foundry. For that reason, of course, they had to put up with men like Mr. Pritchard and himself. It was hardly fair to blame them if they were not prepared to train better men. Another point that had always struck him was that the poor foundry was badgered from pillar to post. As Mr. Pritchard had pointed out, production had very often said: "We must have cast iron that will mill at about thirty inches per minute." Service said: "Oh, we must have cylinder castings that give us about one thousandth wear every fifty thousand miles." They had not reached that point yet, and if only there was some final arbitrator definitely to lay down these points, they would all be very much relieved. Then again, they had the question of facing so many revisions—of producing at about fifteen shillings per hundredweight castings such as automobile cylinders, which might involve anything up to forty cores, all of which must of course be dead accurately placed—perfectly correct in contour—must not by any chance cause a blow-hole nor wash when pouring—slipped together accurately in about five minutes—if they were to get wonderful production. That was not so easy. He had seen the sand slinger at the Ford River Rouge works making cylinders. They did not get cylinders like that to make in this country. He did not know whether any of them were curious enough to observe the half-pattern which was on the plates. There were no out-

standing projections—it was in one piece. There were a couple of body cores with the cylinder barrel cores back of them and that was the lot. There was a vast difference between that and modern type highly efficient English cylinders. Furthermore, Mr. Ford was, or had been, having demands from his factory for 10,000 or thereabouts at a time. In this country they had an order, as Mr. Hannay had mentioned, and there was first to be a sample. The sample was eventually submitted and occasionally was approved. They must have so many and thus we speed up to get that, say, a hundred per week. Then the sales department say that sales have dropped off and "We don't want any more for two months." When the next order came along you had to get another gang together, or the old gang, and start again. Efficient production in the foundry was constant production, whether it was little or great. It was continuity that counted and it was up to the sales departments and other people to ensure continuity. Mr. Wilkinson had touched very briefly on permanent mould castings. There were a number of gentlemen in that room who were quite familiar with the production of light alloy castings in permanent moulds, and those of them who were accustomed to using them would agree that the production leaves very little to be desired. On the percentage of rejects, he said to Mr. Hannay that he would very much like to limit rejects to three per cent. Their uniformity of dimension was really very surprising indeed when you were dealing with rough castings such as automobile gear boxes. There the continuity was assured, because the difficulties of production necessitating the making of costly and expensive machinery forced it upon the user.

Mr. R. H. Youngash remarked that it seemed rather unfair to call upon an ordinary engineer to speak at a gathering of that sort. He had been very interested in listening to Mr. Wilkinson, who had paid a wonderful tribute that evening to the mechanical engineer. Really, the whole paper went to show that it was the mechanical engineer who was forcing the foundrymen into something better. Comparisons were continually being made between the machine shop and the foundry and it seemed to him rather stupid, because they had exactly the same position and the same troubles, to some degree, in the machine shops. They had changes of designs—they had multiplicity of operations of which the foundrymen had very little conception. On the top of those, they had the one which Mr. Hannay raised, of variations in machine ability. With regard to the permanent die casting, he thought everyone would agree that a most remarkable advance had been made in the foundry during recent years. If they could get larger castings, particularly in iron, to the same degree of accuracy as light alloy die castings, the foundry might reasonably claim to have advanced with production. In any case, it was just as well to notice that it was highly possible that the foundry existed before

the machine shop, so that the machine shops had a later start but have eventually well passed the foundry—relatively at any rate. Mr. Pritchard had referred to the training of people for foundries. He did not think there should be any difficulty in that direction. He quite agreed that no foundryman should ask his directors to spend £1,000 on machinery to improve the time of casting one minute, but surely, with all the science at their disposal and the various universities, the whole field of metallurgy had been thoroughly covered and the foundryman was equally able to take advantage of developments as the mechanical engineer.

MAJOR VERNON BROOK said Mr. Hannay had challenged Mr. Wilkinson to vindicate modern foundry methods and prove that they had kept pace with other engineering methods. He thought Mr. Wilkinson had done that. The American motor car factory was at a great advantage over the British motor car factory because of the enormous and continuous production over there compared with what they get here. It seemed to him that not only in the production of motor car castings, but in iron castings they were more difficultly placed here than in the States. There was one thing to be said in favour of the British foundryman. That was the very highly increased use of compressed air for operating large jarr-ramming machines, though there were still many foundries where compressed air was comparatively unknown. The question of sand slinging versus jarr-ramming had been raised and he would like to ask Mr. Wilkinson whether he considered that the slinging method was better in most cases than the jarr-ramming. Mr. Wilkinson had referred to tumbler machines, in which cylinders were tumbled. He thought the answer to that was that they were Ford cylinders. He could not see many English cylinders being tumbled—they did not seem to lend themselves to that. Then there was the question of conveyor plant. Many of the slides shown seemed to show conveyor plants to deal with the moulds and sand but not to deal with the metal. Mr. Wilkinson had referred to the time required for cooling sand. He had stated that in most of the American foundries forty minutes was considered enough, and that in the Citroen factory they considered thirty-five to forty minutes sufficient time. He would like Mr. Wilkinson's views on that. Mr. Hannay had brought up the question of scrap. Mr. Hannay and he had had a good many scraps in the days of the war and apparently he was still of the same opinion, that there was too much scrap. One would think that modern methods should have reduced scrap to at least reasonable figures. Mr. Pritchard and Mr. Player had blamed the designer for that. He thought they must be right, because one knew that certain parts for identically the same purpose, produced for one motor car, gave a good deal more trouble than similar parts for other cars. Designers would perhaps take that to heart and see what could be done to

reduce the proportion of scrap in that connection. Mr. Wilkinson did not say much about die castings, but he was glad to hear that it was appreciated that very great strides had been made. The tendency to-day was not mainly in the direction of gravity fed castings, but in the direction of pressure castings in which very much finer limits were possible. That type of casting would, he thought, simplify many of the problems which had arisen in foundry practice. In connection with that, one would say that the old hit-or-miss method of producing die-castings which existed only four or five years ago in the foundry had entirely disappeared, and he claimed that die foundrymen had shown greater enterprise in overcome the difficulties of contraction. Another point Mr. Wilkinson did not touch upon was the analysis of all the metals; careful watching of the temperature and pouring times, and he thought we could safely say that a great deal more attention was paid to the mixing to-day than was paid a few years ago. The foundrymen had made great strides and it rested with the designer to co-operate with him more than he had done in the past.

Mr. F. J. Cook said he was, perhaps, in an unique position, in as much as he was an engineer before he was pitchforked, thirty-two years ago, into the foundry and would look at the question through both spectacles. He was struck at the start by the different mentalities of the engineer and the foundryman. The President started by pre-judging the paper before he had heard it and by giving people the impression that there was nothing good in the foundry. The engineer would accept an American machine which contained castings he would not look at if he had to produce the same article in this country! Mr. Hannay had referred to scrap in the foundry. Mr. Cooke wondered whether there was any scrap in the machine shop and what chances there were of eliminating scrap in the machine shop compared with the foundry? They had to work in the negative—to work with stuff they could not see and could barely guess about—whereas in the operation of machines engineers had the positive before them all the way through. If people knew more about the foundry, they would wonder that there was ever a good one produced, rather than that there was sometimes a bad one. Another point was the time at which the sand was used. Forty minutes was given. He had seen a foundry where sand was used over and over again every fourteen minutes in the production of radiators. There was a wheel with three platforms, going round horizontally. The platforms came up, the mould was made, put on and it went to the other side where it was cast, then to the platform below where it was taken away and the sand came out at the other side. That shop was doing the work of a five-acre foundry.

Mr. Wilkinson replying, said he was much obliged for the way in which they had received the paper, and to his foundry friends

for backing him up so well. He thought they had convinced the others because they had hardly said a word! Mr. Hannay was speaking about blast furnace metal. Ford, of course, used a great deal, from what one heard, for his cylinders, but he struck so many bad patches that he had had to give it up. The main reason was the metal from the blast furnace was never uniform. At the top you put in ore and coke and limestone. You could use your own judgment as to what was going on. It was not a place you could put a foot rule inside. It needed a remarkable amount of skill to gauge it. The metal coming out at the bottom was always more or less variable. If you took twenty-five to thirty tons at once, it was very seldom that the metal was one grade. Many years ago the steel plants were taken with a desire to use direct metal. They got over it in a very simple way. They built large receivers—anywhere up to 300 to 400 tons of varying grades of metal were put in. Naturally, one kind of metal neutralised the irregularities of the other, and by preheating this receiver and keeping it heated with a flame, they got over the trouble and it came out really uniform metal. Ford, he believed, was, or had been, trying to use electric furnaces for making the metal homogenous as it came from the blast furnaces. Certainly, there was no questioning the fact that casting metal into pigs and then examining and grading it was far and away better. There was frequently a very high percentage of carbon in cast metals which was discharged as "kish." As Mr. Pritchard had said, specifications to-day would not permit the use of direct metal for engineering castings. He would like to point out that the foundryman certainly was not content to take his bad castings back. He always did it under protest. He had never come across a foundryman who did not want to make his castings good. Referring to scrap castings, the correct percentage of scrap castings was nil. That was the percentage that foundrymen wanted, and sometimes they would get much nearer to it if the engineer was more reasonable. Most foundrymen would agree with him that when you supply really high grade castings to an engineer, he was usually rather more critical on the quality of those castings than he was if you supplied a large proportion of defective ones. The point is that many of those castings were usuable. When the engineer was pushed for the casting he would use it and make a success of it. Why should he consider it defective when he was not pushed? Mr. Hannay had also asked about the weight to be carried about in the centrifugal process. He really could not say. In the ordinary casting, he thought the weight of metal handled amounted to one-third of the amount handled. He did not agree with Mr. Pritchard that the foundry had not progressed quite as much as the machine shop. In his opinion, the foundry had progressed remarkably. One knew the machine shop had made wonderful

progress and, while the engineer had been advancing, the foundryman had not been lagging behind by any means. He certainly agreed that the foundry was not looked after from the point of view of capital. Many times he had looked with envious eye on the machine shop. He thought they did remarkably well with the small amount of cash that was granted to them! Most heartily did he agree with Mr. Player's remarks regarding the Ford monoblock. If they had only got those to make, couldn't they turn them out! It was the simplest casting he had ever seen and it was a wonder to him that they had ever made a defective one. That was one reason why Ford got such remarkable production.

Mr. Youngash had talked about variations in castings. The whole of the machine shop practice had been developed upon the well recognised fact of the impossibility of dealing with hot, molten metal within very accurate limits, unless the metal melts at a comparatively moderate temperature. It was absolutely impossible closely to control the limits of castings made with a metal that melted at anywhere from 1,300° to 1,500° Centigrade. It was the recognised impossibility of dealing with those that led to the development of the machine shop.

As regards barrelling cylinders, a number of Americans did it because their cylinders were far more substantial than the average British cylinder. Mr. Cook had said something about the amount of time sand was allowed to stand. He did not know that it went as low as fourteen minutes. He did not think that was wise. Sand, when it had stood a while, was in a finer state of temper than when it was mixed up immediately. One could not have it too well tempered for making really good moulds. That was why, he thought, that the large tank for storing the sand was a wise thing. In preparing his paper he was very strongly tempted to devote a considerable amount of time to die-casting, but came to the conclusion that it would be far wiser to stick to what he could handle. He knew quite well that no one could dispute for a single moment that die-castings had made enormous advances, whereas he was afraid some of his engineering friends did require a little illumination on general advances in foundry practice. If he could lead them to think more kindly of the foundryman and prove to them that he might be a worthy assistant in the march of progress, he would be more than rewarded for his trouble.

BOLT MAKING BY THE HOT FORGING AND COLD PRESSING METHODS.

Paper presented to the Institution, Birmingham Section, 6th March, 1929, by E. J. Wiley.

BOLTS, nuts, and rivets are used so frequently in the engineering trades, and are obtainable so readily, that little curiosity is aroused as to the methods in use for their manufacture. Until about a century ago they were made by hand forging on the anvil, but the increasing demand suggested the need for quicker means of production. An examination of the patent records from 1830 indicates that a number of individuals were turning their attention to the possibilities of machine forging, and two distinct types of bolt making machines known respectively as " solid " die and " split " die headers were being evolved.

It will be easier to understand the principle of both kinds by a study of the tools used in them. In the case of the solid die tools, the pin to be headed is cut to the required length on a bar shearing machine, and after being heated in the furnace is placed into the bottom die. The knock out pin takes the pressure due to heading and also serves to eject the headed bolt. The " split " die tools prevent the bar from moving during the heading operation by gripping it between the two half round grooves. The earliest type of " split " die machine was known as the Foot Header. The method of operating this machine was to grip the heated rod between the dies, which were closed by toggles attached to the foot lever. The required amount of metal to form the head was upset by hand hammer and was then finished to size in a suitably shaped groove at the side. The " Oliver " was acknowledged as the first " solid " die machine. The original one was built by Thomas Oliver, of Darlaston, and first described in 1838, but undoubtedly in use before then. This was another early improvement on the anvil method of forging bolts, because it enabled the forger to dispense with his helper, or " striker," and make greater use of " fixed " tools. In the general arrangement of this machine, the hammer, swinging on a cross bar, is caused to descend by pressure on the treadle and is raised again by a spring. The bolt has an excess of metal, or " fraze," which has to be removed by " dressing up " in a swage of suitable size. This surplus metal is a featuree ommon to all bolts made in " solid die " tools.

The first power operated " solid " die machine was a vertical press having a sliding saddle to enable the operator to push the

bottom die carrying the heated pin under the heading tool and afterwards withdraw the headed bolt as the slide ascends. In the case of a double ended vertical bolt header or "slide" machine, there are two saddles carrying bottom dies to each slide, these being necessary because it takes two blows to make bolts having heads to Whitworth standard sizes. The usual kinds of bolts described as hexagon head, square head, countersunk head, and cup square, can be made on either the "solid" or "split" die machines. Bolts up to any length can be forged on the "split" die type, also exceptionally short ones are produced with less trouble than on the "solid" bore machine. This is due to the fact that shearing to length is the last operation and the forging is completed on the heated bar before cutting off. An objection often raised against the split die system of forging is that a fin is left under the head where the dies meet. Careful tool making, and the use of a machine of ample capacity for the size of work, will reduce this finning, until it is of no consequence on a forged bolt.

In the case of rivets the "fin" under the head is regarded as a bad feature, and many users will not accept them unless they are smooth underneath. The Board of Trade will not allow "finned" rivets to be used in steam boiler making nor on certain classes of constructional work. In consequence of this, nearly all rivets are made in solid bore forging machines. In some countries no objection is made to this fin, and therefore greater use is made of "split" die rivet "headers." When large quantities of rivets have to be made without fin, the rotary table rivet header is an excellent machine for the purpose. In this machine a number of solid bores are fastened to the rotating table, and heated pins of suitable length are placed in each bore as it comes to the front of the machine. The table rotates and is indexed to bring each bore in turn under the vertical slide carrying the heading tool. The completed rivet is ejected at a later station. The daily output of $\frac{1}{2}$-inch rivets from this machine is from 70 to 80 gross.

The small amount of metal required to form a rivet head can be evenly compressed in one blow, but in the case of bolt heads made to Whitworth standards, the length of metal to form the head is so long that two blows are necessary to ensure a perfect head. It is not a question of power which prevents the forging of Whitworth heads at one blow, but the impossibility of keeping the heated metal from bending before it is fully compressed. The heated metal behaves like a strut and will compress evenly when the ratio of length to diameter is below a certain figure, but will bend when this figure is exceeded. It has been proved by experiment that the maximum length of metal which will compress evenly around its axis is three times the diameter of the bar. With this ratio of length to diameter, perfect uniformity of section and dead square ends are essential to give uniform flow without bending. Under

ordinary shop conditions it is impossible to obtain perfectly square ends, and to compensate for this imperfection it is advisable to reduce the ration figure to $2\frac{1}{2}$ to 1. A perfect upset can then be produced, and Fig. 8 shows an etched section of a forging made to comply with this rule.

When making bolts to Whitworth standard sizes, the length of "stock" required to form the head exceeds this figure, and two blows must be used to "gather" the metal. Any attempt to form the head of a standard bolt with hexagonal or square head at one blow, will result in failure. The reason for this is that as the heading tool advances the metal will bend. As the heading tool advances towards the bore, the "pin" will bend still further, and at the completion of the stroke there will be an excess of metal on one side and insufficient to fill in the impression on the other. To overcome this difficulty and to make bolts with strong well-formed heads, it is necessary to use a first operation tool to control the lateral movement of the metal.

This process is known as "bunting," and the tool is called a "bunt." The impression in this tool is shaped like the frustum of a cone, and experience has proved that best results are obtained from "bunts" made to particular dimensions. When large headed bolts have to be made containing from seven to ten times the diameter of metal, great care is necessary in proportioning the "bunting" tools.

The fact that a first operation or "bunting" tool is needed when heading bolts to Whitworth standard, makes it impracticable to use any of the rapid production machines, designed to work on the single blow principle. The desirability of reducing the sizes of bolt heads has been urged on previous occasions, but the old standard is still adhered to. Quite recently the British Engineering Standards Association has issued Report No. 193, giving recommended sizes for bright bolts having smaller heads and Whitworth threads. Perhaps in the course of time similar recommendations will be made for forged bolts.

Material.

Some years ago nearly all bolts were made from wrought iron, and steel bolts were regarded as troublesome things. Owing to improvements in steel making and the ease of obtaining suitable qualities, the position is reversed. To-day, genuine wrought iron bolts are regarded as "specials." Usually, a mild steel of about 28/32 tons tensile is utilised, but there is an increasing demand for bolts made from the higher tensile steels. The operations performed on the rolled bars to change them to finished forged bolts vary a little according to the type of machine used.

The "Slide" Heading Machine.

Given good conditions, one operator working a double saddle

" slide " machine will head from 35 to 40 gross of $\frac{5}{8}$-inch hexagon head bolts per day of $8\frac{1}{2}$ hours. The heated pin—handled with tongs—has to be inserted in two different bores and removed in about five seconds to give this output. It will be realised that only operators with the necessary skill and strength can maintain such a rate of output. The heads of bolts made on this machine have an excess of metal, which has to be removed by a trimming press. The operation is called " stripping." This surplus metal is waste and adds somewhat to the cost of production. The method of working the " slide " machine is to have a youth to heat the " pins " at the furnace, a man to work the heading machine, and a youth to operate the " stripping " press.

" Split " Die Machines.

The " split " die headers are sometimes arranged to work with three operators, but it is more usual to forge the bolt to a finish on the one machine and so obviate the stripping process. With a furnace located near to the forging machine, one operator heats the bars and forges the bolt to the finished stage. A good day's output working under these conditions would be 15 to 16 gross of $\frac{5}{8}$-inch Whitworth hexagon head bolts in $8\frac{1}{2}$ hours. After the head is forged the operator cuts the bolt to the desired length of shank on the side-shear of the machine.

Formation of Metal in Bolt Heads.

A soundly formed bolt head should have an even spread of metal around its axis. A bolt of this kind will have maximum strength and it may be interesting to compare the section with that of a bolt made on a single blow machine.

The single blow bolt has been made on the American hammer type machine, and although in outward appearance the finish is excellent, it will be seen how very unsatisfactory the internal structure is The hammer header will make good bolts with small heads and is capable of rapid production (The author showed on the screen the section of a bolt made on the " split " die machine by feeding the metal forward twice in the same groove and consequently doing away with the " bunting " tool.) At one time this method of heading was not regarded as good practice, but it has been proved that the opinion was based on a theory which did not take all factors into account. The bolt shown was an average specimen and it must be agreed that the distribution of metal is particularly good, while a large number of physical tests prove beyond doubt that bolts made in this way compare favourably with those made by any other method. The latest type of bolt heading machine works on the " semi-hot " principle, and is completely automatic. The rolled bars are heated in a long furnace to a dull red temperature and are fed by grooved rolls into the

machine. A headed bolt is produced at each revolution of the crankshaft, and very rapid production is obtained. Compared with the non-automatic types it will produce three to four times more. A point in this machine is the massive construction of the frame, the long heading and gripping slides, and the elaborate oiling system. These are essential features in a machine giving heavy hammer blows at the rate of 120 per minute. Unfortunately, this machine cannot be used for making bolts to Whitworth sizes, as it operates on the single blow cycle.

Furnaces.

The selection of furnaces for bolt heating is a matter for very careful consideration, for they represent an important item in the total cost of production. So far as fuel is concerned, there are furnaces in operation using solid fuel, oil, and gas. Judged on a fuel cost basis, the solid fuel furnaces are the cheapest, with oil next, and gas the most expensive. There has been great improvement in the efficiences of both gas and oil furnaces during the last two or three years, but there is still need for further progress. Taking overall costs into account for coal, oil, and gas fired furnaces, the difference is not so great, and in certain cases the saving of room and improved shop conditions which obtain when using gas, more than compensate for the increased cost. The fact that a small compact gas furnace can be placed close up to a forging machine increases output due to the operator having less distance to reach for the heated bars.

The efficiency of forging furnaces used for bar heating is very low when compared with those used for heat treatment, etc. This is explainable to some extent by :—

1. Radiation loss from brickwork, which cannot be avoided, as it is impracticable to employ insulation.

2. Loss in flue gases, as little advantage can be obtained from recuperation.

3. Loss of heat through the charging holes.

4. Loss of heat along the projecting bars, as only the ends are heated.

When solid fuel is used it is not uncommon to find efficiences lower than 5 per cent. Another item adding greatly to production costs when coal furnaces are used is the rapid wear of the forging machines, due to grit getting into the working parts. General shop conditions are very much improved by the use of oil or gas as fuel, and ideal conditions are attained when using gas. With oil at 80/- per ton and gas at 5d. per therm, the heat units will cost about twice as much from gas as compared with oil. This difference is very large, but it has to be remembered that the price

paid for gas fuel represents the cost at the furnace, whereas with oil the following charges must be added :—

1. Storage.
2. Provision for keeping the oil at a temperature between 60° and 100° F to ensure easy flow through the pipes and burners.
3. Pumping to give the required head of pressure to feed the burners.

The utilisation of heat in the furnace has to be considered in addition to the cost of heat units, and in this connection gas shows certain advantages due to the ease of control. Taking the efficiency of the forging furnace on the basis of total heat units supplied as input, the heat extracted by the work produced in an average day as output, the figure is, of course, much lower than that obtained by a short period test with furnace producing at maximum speed. The figures given in all cases have been arrived at in this manner. An oil fired furnace of very good design, heating " blanks " for bolt making gave an efficiency of 8 per cent., and after being fitted with a pre-heating device for the air supply, there was an increase to 10 per cent. A gas fired forging furnace fitted with recuperator and heating nut bars was tested for a period of three weeks, and the result was about 18 per cent. efficiency. It is unlikely that such a difference exists in all cases compared, but where it does, the choice of fuel becomes a matter of convenience. The character of the heat best suited to bolt making is usually described as a " soaking " heat, which results in the core of the bar being at practically the same temperature as the outer surface.

Cold Forged Bolts.

The manufacture of wood screws by the cold pressing method was carried out as long ago as 1760.

In 1831 a patent was granted to Daniel Ledsam and William Jones for a machine to make wood screw blanks, rivets, etc. The operation of the machine is described as follows :—" Into the machine designed for rivets, etc., the wire or rod is drawn by grooved feeding rollers, actuated at a corresponding speed by tooth wheels which are caused to move intermittently by a ratchet and pawl, the wire passing through a tubular guide, and thence through a cutter into holding dies, the length depending upon the action of the ratchet, which is adjustable. By a lateral sliding movement of the die the length of the wire held between them is cut off and carried to a position exactly opposite the heading punch, which is forced up by a lever that obtains motion from a revolving cam. The punch operates upon that portion of the wire which protrudes through the dies, forcing the metal to spread laterally, the part formed of the head depending upon the shape of the cavity in the punch, or the recess formed in the dies." These words could be used to describe the present-day machines, except that the latest ones have the heading slide directly connected to the crank shaft.

Cold headers are designed as "solid die" and "split die" machines, and both types are made to operate on either the single or double blow principle. Where heavy upsets are required the three blow cycle is used, and for special shaped pressings having a comparatively short length of metal in the "upset," this machine is often the most efficient. For standard bolts with hexagonal heads, and for cup square bolts, the open die, double stroke machine is the most popular. Bolts having a length of more than eight diameters must be made on the split die machine, because of the difficulty of extracting them from solid bores. It is the practice in this country to cold press bolts up to $\frac{3}{8}$-inch diameter, the larger sizes being produced more economically by the hot forging method. Machines for bolts up to $\frac{1}{2}$-inch diameter run at 240 r.p.m., and as two blows per bolt are given, the output is 120 per minute. As to the stages in making the bolt, the wire is cut to length part upset by the first tool and finished by the second. The metal to form the head is made in the shape of a cheese of sufficient size to enable the hexagonal or square shape to be sheared from it. This shearing or trimming operation is performed on a press which works automatically and produces at the rate of 80 per minute. The larger diameter bolts can be, and often are, made by the cold process, but when this is done the bolts are for use in place of the bright finished ones turned from the bar. Where the black finished bolt is accurate enough, the sizes $\frac{1}{2}$-inch and over are produced more economically by hot forging. The quality of the steel used in cold pressed bolts is of great importance, and although it is fairly easy to obtain steels sufficiently low in impurities and carbon to stand the cold working, more care is needed to make a steel which after cold working will give a strong reliable bolt.

Very low carbon steel known as dead soft quality is sometimes used for bolt making because of the ease with which it can be manipulated, but it is obvious that the finished article cannot give reliable service. The use of soft steel for bolts has resulted in many users refusing to consider them, but this opposition is gradually disappearing, particularly where careful tests have been made on bolts produced from steel of suitable quality. To obtain satisfactory results the steel as received, in coils, should be cold drawn to size and afterwards fully annealed. The internal structure of the steel, after heading has taken place, is entirely changed, and when examined under the microscope shows elongation of the crystals, especially where the head joins the shank. This feature is more noticeable as the diameter of the bolt decreases when making heads to Whitworth standard, because of the increased length of metal, in proportion to its diameter, to be upset. While in this condition the bolt head would very easily break off and careful heat treatment is essential to normalize the metal. In order to obtain bolts of sufficient strength to stand up to their work, it is

essential to use a steel of a quality which after heat treatment will have an ultimate tensile strength of about 30 tons per square inch.

When bolts are required to carry very heavy loads they can be produced by the cold pressing method from steel to give from 45 to 50 tons tensile. If proper care is taken in the selection of the steel and its subsequent heat treatment, the strength of the finished bolt will be entirely satisfactory when compared with bolts made in any other way. A source of weakness in any bolt is the sudden change of section where the shank joins the head, but by upsetting the head from a wire equal in diameter to the shank size, the grain of the metal flows in a curved path into the head and so gives the greatest possible strength at this point. That this is so is proved by the following test. A standard $\frac{5}{16}$-inch Whitworth bolt was turned on the top of the head until its thickness was about $\frac{1}{8}$-inch. The end of the shank was gripped and the pull taken by the under side of the head against a plate having a hole $\frac{1}{32}$-inch larger than the shank. The bolt broke on the shank about half way between head and grip at a total load of 2.67 tons, or well over 30 tons per square inch. The saving of material together with the speed of production makes the cold pressed bolt an attractive proposition, for a completely heat treated article having a strength of 30 tons tensile or more can be sold at a lower price than the untreated one made by turning from the bar.

As bolts are usually required to bind two components together, it is of vital importance that they should have a high elastic limit together with a good elongation figure so that they will not easily stretch and yet be free from brittleness. Lack of attention to the above points has been responsible for the introduction of patent lock nuts, most of which are useless, for the trouble they set out to cure can be prevented by the use of a suitable bolt and one of the several well-known locking arrangements. It is a common sight to see the standard lock nut fitted after the standard thickness nut. This is wrong, for the lock nut should always be fitted next to the piece to be gripped, and when arranged in this way best results are obtained. It is impossible to treat every point which arises during the manufacture of bolts in so short a space, but it is hoped that sufficient has been said to give a general idea of the methods in use.

Discussion.

Mr. H. G. Povey said he thought everyone was in agreement with Mr. Wiley that it was a surprising fact that cold heading had not been more used than it was, when one considered the advantages there were, such as saving material, which was a very important item. As an example of that, take the little platinum pin used in the magneto case in the electrical trade. That little pin was very successfully headed in the form of a cheese from the

wire size at the rate of 140 a minute, with practically no percentage of scrap. Look what that saved one on an ordinary turning job. He presumed one would tackle that job on a medium precision bench lathe or turret lathe. That illustrated the advantage in the saving of material and there was, on the other hand, a great saving on production. Mr. Povey gave details of the manufacture of pins for Lewis gun magazines during the war, illustrating the great saving, in cold heading, of floor space and production.

MR. R. H. YOUNGASH remarked that his knowledge of the nut and bolt trade was confined largely to the use of them. It was interesting for those not familiar with the operations involved in making such homely articles, to see the varied methods and the kinds of work involved in producing these comparatively simple pieces. It was rather curious, he thought, that there had been no substantial advance in the method of manufacturing bolts since 1831. He assumed that there had been some advance made in the bolts themselves in that time, although with respect to black bolts, he could not find much to say in their favour. It was usual to buy black bolts from half a dozen places and to have half a dozen sizes of thread. Mr. Wiley had carefully explained that his paper had had more reference to the actual manufacture of the bolt than to the screwing. It was the fashion nowadays to condemn Whitworth heads. Perhaps they might go further and say they would condemn Whitworth screws! He thought the trouble was largely due to the crude way in which they were screwed. When Mr. Wiley made a comparison with bolts produced on automatic machines, it was just as well to remember that one did not usually make mild steel bolts in any quantity in that way. The machine made bolt was usually made of the higher tensile steels, forty to forty-five tons or thereabouts. While he thought that in America they had somewhat more substantial figures in that direction, so far as this country was concerned, he did not think there were any bolts being produced by cold heading or hot heading, of that particular class, that would pass the ordinary every-day inspection tests for accuracy. With regard to the non-use of cold-headed bolts, it was largely due, he thought, to certain conditions not easy to avoid. For instance, many forms of construction recommended by Lloyds and Admiralty specifications, War Office and such like, very carefully avoided the use of cold-headed bolts, possibly, as Mr. Wiley said, because the early efforts were so poor. He felt sure the worst cold-headed bolt was better than the hot headed black one. Really, there was very little use for the common black bolt in modern industry, so far as he was familiar with it.

MR. E. W. FIELD said that there was no doubt that the cold headed bolt saved a lot of material, but Mr. Wiley had rather led them to think that they wanted a better system of mass production. The average engineer, nine times out of ten, got a few bolts on

the product which had got to have very special shaped heads, not necessarily Whitworth. So far as he could see, the hot bolt had very little prospect because of the cost of producing as against a capstan, which was a comparatively cheap machine. He would like to have heard Mr. Wiley express his opinion on thread rolling as against cutting. He was quite right about lock-nuts. He thought cold-headed bolts were not used to any great extent because so few of them really knew how good they were! He had seen very excellent results hitherto, and the slides that night had confirmed the opinion. The makers of bolts suffered so much because the cold headed type were made in the same factory as the black bolts, and they had not got a very good name. As an engineer in connection with a fairly high-class product, he did not use them, but he did fasten a few machines down with them. Mr. Wiley's paper had dealt with a subject of which quite a number of them knew very little. After all, even a small unit such as a nut or bolt had got to be made, and got to be made at a price, and he thought Mr. Wiley had shown them that he could get some output.

Mr. J. A. Hannay, President, said that when Mr. Wiley was telling about the number of diameters that ought to be compressed and the shapes of heads, his mind went to the formation of a valve as they know it, the ordinary poppet valve. If Mr. Wiley had time, he would like him to tell them how he would form that. He was surprised to hear him talk of throwing the hot pieces of metal about. He should have thought they would have got some better method of handling it. He was struck with the possibilities of the circular table and thought there were great possibilities there for enormous production. If that was adapted with cold heading, they should be able to do anything. He did not know whether the bolt making industry had yet been able to tackle electrical heating. There are some very wonderful things in electrical heating which saved the throwing of the material about. The point he was most interested in was the fact that the bolt makers had realised that there was something in the flow of the material, and those few slides where Mr. Wiley pointed out the way the material flowed gave him great encouragement and hope for the bolt makers. They are going in the right direction. Many bolts, black bolts and many cold headed, he had been frightened to use for really critical work. He had done almost all he could do during the last few years to cut out cold-headed bolts where there was any strain at all. He felt a little bit safer now that bolt makers were beginning to study the material and find out something about the flow of the material. It was a most encouraging sign. A short time ago he happened to be in the U.S.A. and saw some bolts being made in the Ford works. Some of them were the crudest things he had ever seen—a bolt about one and a half inches long and three-eighths inch diameter,

hexagon head, but there was not much hexagon. He did not suppose there was much more than one-sixteenth inch flange. They were made cheese head, bevelled, then sheared into hexagon and then passed right to a machine where the threads were rolled. Mr. Youngash had referred to the making of bolts on automatics, etc. Mr. Wiley might be interested to know that at the present time something like fourteen million pieces, in the way of bolts, etc., and headed pieces, were being made on automatics because they must have really high tensile steel. At present, in Birmingham, about one-quarter were being made, and something like four million bolts were being bought out, so that there was an enormous field. It showed that the users as yet had no confidence in the ordinary bolt maker for these high tensile bolts.

MR. J. INGHAM said that Mr. Hannay had put his finger straight on one of the weakest points in connection with bolt manufacture. Mr. Wiley had referred to throwing material about, and the President had put his finger straight on that spot. He believed that that was one of the big problems that they as bolt makers had to deal with, that was, the movement of material from the rolled bar until it went out of the works. Not through the machinery but the actual handling of the material from process to process. He would say that the industry, as a whole, had not tackled that problem sufficiently well, but the younger men who were in the industry to-day had been brought up in a school in which they knew the importance of that problem, also the flow of material. There was a lot of good work being done in this particular district in that line just now, and in Germany there were three or four firms, very important firms, so that it was possible that even with such a prosaic article as a bolt, they were dealing with movement of material in a manner which might be impracticable to people who were dealing with the movement of material through a motor car factory. One wanted to get away from that idea. The lecturer had referred to the question of furnaces. It seemed a very terrible thing to hear of efficiencies of only five per cent., but he assured them that if they tackled the question of the efficiency of a little furnace for heating bolts, a furnace that was only perhaps about two foot six inches long and about eighteen inches square, they were right up against it to get high efficiency. But the figures of the lecturer were not the best figures. He had seen furnaces working at nearer 25 per cent. efficiency without any extraordinary apparatus at all. He thought it just to claim something that the bolt makers were doing.

MR. G. H. RUTLAND said that the term "Darlaston" nut had usually been applied to one that could only be turned with a spanner, but from the talk they had had that night he thought it was fairly obvious that there were movements towards accuracy. He would like to emphasise Mr. Field's point about patent locknuts

and about the cold thread rolling. Hot thread rolling was being done in some of the works in the Darlaston district. Speaking of furnaces, he wondered if the Mond gas had been tried, and how the efficiency of Mond gas compared with town gas? He agreed with Mr. Wiley on the point he had made with regard to the locknut. It was quite a common failing with engineers who fit locknuts.

Mr. Wiley, replying, said that he would first deal with the question of upsetting metal. There were certain laws governing that operation which must be followed to get satisfactory results. Those rules were first explained by Mr. Frost, of U.S.A., and were published in a paper given before one of the American drop-forging Institutions. The motor car valve, made in alloy steel, could be forged on the upsetting machine, and if correctly proportioned tools were used there would be an even distribution of metal resulting in greater strength than could be obtained by machining from the bar. In explaining the operation of bolt heading, he had mentioned that the heated "pin" or bolt "blank" was thrown to the man working the heading machine, but he did not intend to give the idea that the metal was thrown about unnecessarily. This practice was followed because it happened to be the quickest way of doing it and the operators become so expert with the tongs, they almost caught the heated pin before it got there. It was important to form the head without too much loss of heat. Electrical heating had been considered, but at present it was not an economical proposition. The cost of electrical current was one of the difficulties, and there were others. Some time ago he saw certain very small and intricate stampings being made and the blanks for these were heated electrically. The well known rivet type heater as used by constructional engineers gave maximum heat at the centre of the blank, but for bolt heading one end of the blank must be comparatively cool while the other end was very hot. A French patent for motor car valve making consisted of a machine with electrical heating all in one unit, but whether this was successful or not he could not say. Bolts made from alloy steels were produced by cold pressing and hot forging. If the quality of steel was suitable for forging it could be made into bolts, and large quantities of nickel steel bolts were made by forging. When accuracy was needed they were made oversize and machined to size on capstan lathes or similar machines. The advantages of the circular table machine had been proved for many classes of work, but its application to cold heading for bolts did not seem to offer any improvements over existing machines. The difficulty would be in the loading time. The present cold headers were fully automatic and it was difficult to imagine a faster production than 120 quarter-inch diameter bolts per minute. He was surprised to hear Mr. Hannay say that he had done all he could to avoid using cold headed bolts, but very pleased to learn that he had changed his

opinion somewhat. In the early days of cold heading there was justification for refusing to use bolts made in that manner. There was no need to feel doubtful about using them at the present time. As a matter of fact they were being used in very large quantities and giving ever satisfaction. They could be made from steel giving an ultimate tensile strain of forty-five tons per square inch. Tests had proved them to be stronger than bolts made from the bar and that was due to the flow of metal as explained. Mr. Youngash had mentioned that certain specifications issued by Lloyds, the Admiralty and others, stipulated that cold headed bolts were not to be used. Well, all official specifications were years behind the best practice. However, there was Specification S.31 which gave particulars of a steel for cold heading for use in aircraft construction. He thought the mention of that might give the motor car people a little confidence, and if so, the bolt makers would be very grateful to hear of another convert to the use of cold headed bolts. In reply to the various question on accuracy, he could only say that the cold headed bolts would satisfy all reasonable tests.

Mr. Field and others had asked for some remarks on thread rolling. The majority of small metal screws had rolled threads, but in the case of bolts the usual practice was to cut the thread with screwing dies. There were good reasons for treating screws and bolts differently, but it would take too long to give a full explanation. Rolling the threads was very much quicker than screwing them, and some people claimed that the rolled thread was much stronger than the cut thread. His own opinion was that any difference in mechanical strength must be very small and was hardly worth bothering about. Very accurate threads could be produced by the rolling process and one firm was making micrometer guide screws in that way. Mr. Rutland had asked about hot thread rolling. The coarser threads as used on railway track screws were produced by hot rolling, but threads of Whitworth form could not be kept accurate enough. Mr. Youngash complained about the Whitworth form of thread but he could not see anything wrong with it. There was a good deal of misunderstanding about the fit of screw threads. You could not judge "fit" by "feel." The fact that there was play or shake between a bolt and its nut was no indication of the quality of thread. The only two dimensions of any importance in a thread were effective diameter and pitch. The top diameter of a screw could be reduced by 20 per cent. with little influence on its mechanical strength. A lot of energy was wasted in attempting to keep outside diameter too close to nominal size. The Wickman gauging system was the best he knew, for it ensured maximum strength of thread together with interchangeability. He was very interested to hear Mr. Hannay's description of the bolts he saw being made in an American motor car factory. That went to prove that when that particular firm made bolts in its own factory,

it had one standard of quality for its own product and another for the bolt makers. Speaking generally, the quality of bolts made in America was very much below the standard for this country.

Several engineers had expressed their surprise on hearing of the attention given by bolt makers to such points as selecting suitable material, flow of metal during forging, etc. The bolt makers would be equally surprised to find that engineers were not aware of it and he hoped that other members of the trade would have an opportunity of telling them more than he had been able to. Mr. Ingham, who is actively engaged in the bolt industry, had mentioned the importance of quick transportation of work between the different operations. Mr. Ingham had paid great attention to that subject and he would be glad to hear him deal with it in detail. The efficiency figure of 25 per cent. for oil fuel bolt heating furnaces was certainly much higher than the average obtained.

Mr. Rutland had inquired about the use of Mond gas for bolt heating. That had been tried but the small use made of it for that purpose suggested that it had no advantage over other fuels. He was pleasantly surprised to hear so many agree on the subject of patent lock nuts. He had rather anticipated that someone would be ready to defend some particular type. Patents for lock nuts seemed to be taken out daily and much time and money was wasted in trying to popularise them.

A vote of thanks to Mr. Wiley concluded the proceedings.

The latest in Production Machine Tools

Cincinnati Milling Machines; Potter and Johnston Automatic Chucking Machines; Warner and Swasey Turret Lathes; Gridley Automatics; Petermann Automatics; Churchill-Cincinnati Centreless Grinders; Churchill Grinding Machines; Natco Multiple Spindle Drilling and Tapping Machines; Cincinnati-Bickford Drilling Machines; Ajax Forging Machines.

Send us particulars of your requirements.
We will be pleased to submit recommendations.

CHARLES CHURCHILL & CO. LTD

9-15 LEONARD STREET LONDON E.C.2

BIRMINGHAM · MANCHESTER · GLASGOW · LEEDS
SHEFFIELD · BRISTOL · LEICESTER · NEWCASTLE-on-TYNE

M.T.564

The Institution of Production Engineers.

COPIES OF PROCEEDINGS

A limited number of copies of the Proceedings of the Institution can be obtained, as follows :—

BOUND VOLUMES: Nos. I., II., III., & IV.
Price, £1-1-0 each.

JOURNAL ISSUES: Vols. V., VI., & VII.
Vol. V. in 7 parts, 7/-.
Vol. VI. in 4 parts, 4/-.
Vol. VII. in 2 parts, 2/-.
Vol. VIII., 12 monthly parts, Subscription 12/-.

Apply to Head Office, 48, Rupert St., London, W.1

Please mention this Journal to Advertisers.